A SYSTEMS ANALYSIS OF THE NAVAL ENVIRONMENTAL DATA NETWORK (NEDN)

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THESIS

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ENVIRONMENTAL DATA NETWORK (NEDN)

by

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Abstract (cont'd)

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by

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ABSTRACT

This thesis is a study of the Naval Environmental Data Network (NEDN). The objective of the thesis is to conduct a system analysis of the NEDN to establish a basis for designing or redesigning a better, more cost effective network. Emphasis is placed on communication costs. The study is in two parts. The first part describes the existing system, the Naval Intelligence Data Network (NIDN) which affects the NEDN, the proposed NEDN/NIDN communication terminal, and other networks which are used for comparative purposes. The second part analyzes the NEDN to establish ways to improve the system. The overall conclusion is that cost effective improvements can be made, in particular, reduction of line communication costs. Specific recommendations for improvements are offered.

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I. INTRODUCTION

The importance of the weather and on scene meteorologists has been demonstrated in past military operations. The timing of the D-Day Normandy Invasion was completely dependent on the weather. Weather information was considered so important to CINCPAC during the Vietnam conflict that a special high priority circuit was dedicated to weather from Vietnam to CINCPAC Headquarters. Commanders need highly perishable environmental data, such as, environmental warnings, analyses, forecasts, and advisories. The intent of this thesis is to analyze the naval weather collection and distribution system with special emphasis on communications and related costs.

A. OVERVIEW

This thesis is an evaluation of the Naval Environmental Data Network (NEDN). The NEDN consists of interconnected systems of digital computers and associated on-line communications including peripheral equipment which was developed to enable the Naval Weather Service to collect, process, disseminate and display environmental data on a high speed, real time basis.

The Naval Intelligence Data Network (NIDN) and the NEDN/NIDN proposed communication terminal are described because of their impact on the NEDN data transmission capability.

A description of the Air Force Automated Weather Network (AWN) which serves the Air Force Weather Service (AWS) is

included as an example of another weather network for comparison purposes. The AWN does interface with the NEDN and some data is exchanged for mutual benefit.

The Defense Department's Advanced Research Projects Agency Network (ARPANET) is described and used as an example of another computer network for comparison purposes. The ARPANET is a system of digital computers, primarily engaged in research, which is interconnected by high speed communication links. The system allows individual research centers to access programs, services and data from any portion of the network in real time.

B. OBJECTIVE

The objective of this thesis is to describe the NEDN and other existing systems, to point out duplications of effort and to suggest improvements within the total system.

A secondary objective is to demonstrate that the Navy can save communication dollars by examining existing services before procuring new services to solve an individual need.

C. NEED

There is a need to train and use communication system specialists who can design, analyze or recommend a system in response to user requirements. These analysts should be tasked to continually review existing user requirements for the purpose of blending them into the most economical system for data transfer.

II. APPROACH

This thesis approaches the NEDN from a systems standpoint. The goal is to eliminate all uneeded operations and make the necessary operations economical, fast, accurate, secure and simple. The achievement of this goal would reduce communication and other costs. One central question was always considered during this study. Could the NEDN information be placed on another network, thereby eliminating the need for a private network of expensive leased lines?

The methodology used was to gather information on several networks with special emphasis on the NEDN and then to review the facts with the above stated goal in mind. Four basic principles in a systems study are suggested by the Pacific Telephone and Telegraph Company.

1. Eliminate where a need no longer exists.
2. Eliminate duplications.
3. Increase speed and accuracy.
4. Apply new methods and equipment when advantageous (Ref. 1, p. 2-1).

Following these principles should result in savings in personnel, space, equipment and material, all of which would result in a significant reduction in costs.

Detailed information on data processing equipment is included because it is directly involved with data communications. Every study of a data communication system must reach into the processing system at both ends to be complete and soundly based. (Ref. 1, p. 2-3).

A. DESCRIPTION OF NETWORKS

1. NEDN

The NEDN system consists of networks terminated at mainline NEDN sites: FNWC Monterey, Fleet Weather Center (FWC) Norfolk, FWC Guam, FWC Rota, FWC Pearl Harbor, and includes Fleet Weather Facility (FWF) Suitland. Figure 1 shows the relationship of these stations, as well as the interface with the AWN and the National Meteorological Center (NMC). The Rota to London data link is included in the diagram and the study even though the Naval Weather Service does not consider this link as part of the NEDN because there is no computer at the FWF London and hence no EDP transmission is possible (Ref. 2).[1] For weather purposes, this link is an analog circuit transferring facsimile (FAX) and automatic picture transfer (APT) information, both of which are subsequently described. There was at one time an CDC 160A computer at London, but it was moved to Rota, Spain.

Inputs to the system are basic meteorological and oceanographic observations. The majority of the collection of data is accomplished by the AWN. Weather satellite data is provided by the NMC. Approximately 30% of the total input is from Navy sources (Ref. 2). Environmental analysis and

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[1]Mr. B.E. Bradford of the NEDN support department, FNWC Monterey was the major cource of information on the NEDN. This information was obtained during numerous field trips to FNWC and discussions with Mr. Bradford.

THE NAVAL ENVIRONMENTAL DATA NETWORK

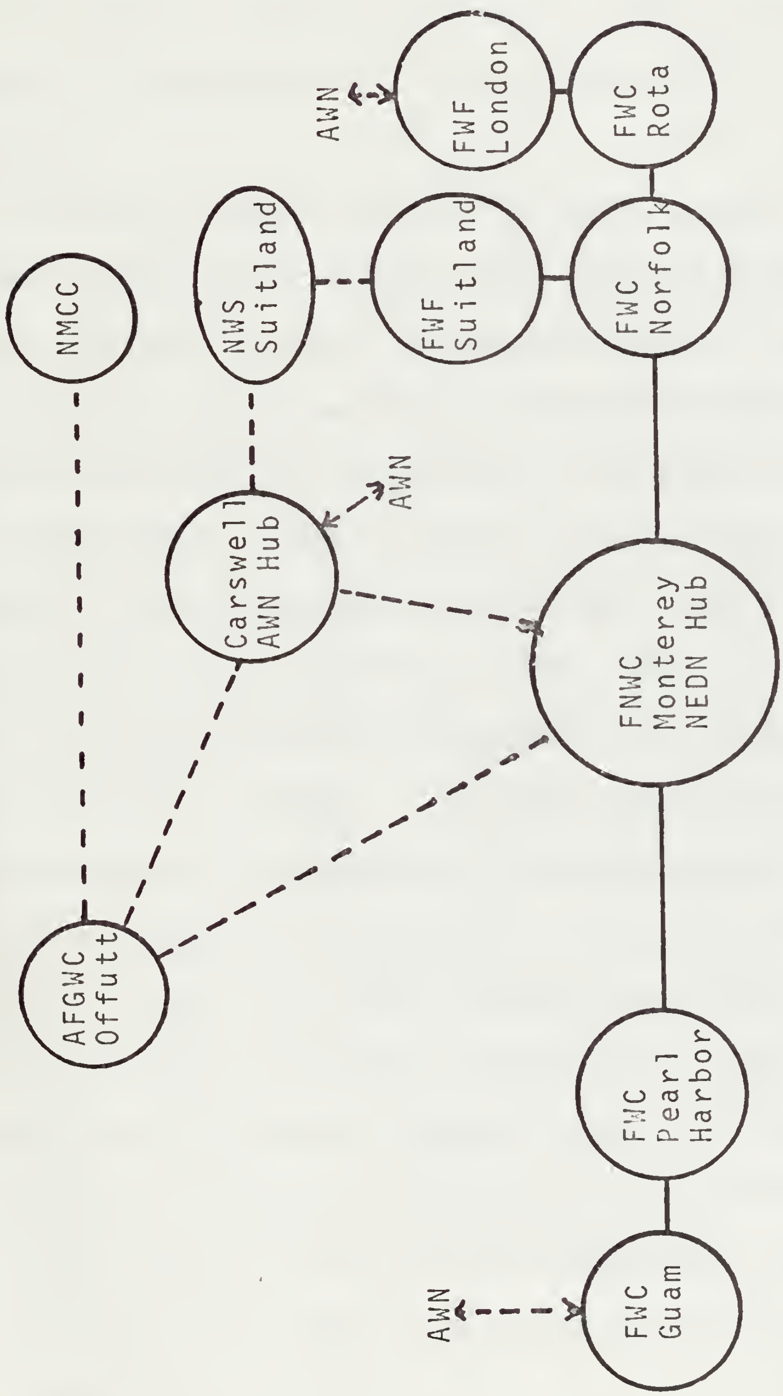


Figure 1

predictions are produced from these observations on a global basis at Monterey and are distributed computer to computer by available communication links to the above NEDN sites. These sites further process and disseminate the data to meet local support requirements. The key function of the NEDN is distribution.

Monterey is the hub of the NEDN system. Two Control Data Corporation (CDC) Model 6500 computers located at Monterey perform most of the computational tasks of the system. The 6500's are hardwired through a satellite coupler to the main communication computer, a CDC model 3200, also located at Monterey. Communication between these computers is controlled by a subroutine on the 3200 notifying the 6500 of the functions to be performed. CDC 8490's at the remaining mainline NEDN sites complete the computer hardware for communications purposes. The data handling capability of these communication computers is approximately 50,000 BPS. A CDC 852 disk system is hardwired to the computational computers (CDC 3100's) at the outlying sites, but is not hooked up to the 8490's at the present time. The 8490's write all messages to the site on magnetic tape. The tape is then removed from the 8490 and hand carried to the 3100. The main processors can back up the data link computers for communication. Older CDC model 160A's are used for fleet facsimile weather broadcasts.

The output of the communications computer goes through an interface/connect which is an electronic computer parallel to serial converter. The interface also adds two hardware synchronization control bits, transparent to the communication computers, to each 12-bit byte. The output of the interface is then fed to a digital to analog FM MODEM which prepares the signal for transmission on dedicated leased lines. Bell System Data sets 203 are used on NEDN east with a transfer rate of 3600 BPS. Model 208's are used on NEDN west with a transfer rate of 4800 BPS. Data sets 201A and 201B, capable of 2400 BPS are used as backup and for dial-up purposes, respectively.

The primary form of data is the field. The standard FNWC field is an 63X63 array of values superimposed on a polar stereographic chart of the Northern Hemisphere. Normally, each data point, representing an environmental parameter at points on the grid, occupies one 16-bit byte. Larger grids are sometimes used to produce higher resolution environmental data from the resulting smaller mesh. The standard grid, consisting of 3,969 data points, would make up more than one transmission block or message if it were transmitted in its full form. Data is therefore normalized and compacted prior to transmission. Normalizing or band-indexing ranges the data around a mid-point and reduces the original data point from 16 bits to 12 bits. These 12 bits contain the sign, integer and fraction of the original data. Compaction is accomplished by computing differences between adjacent data values, then determining the

minimum number of bits required to express the difference value. The compaction scheme normally results in a 4/1 reduction in the amount of data to be transmitted. The technique used is explained on page 2-47 of reference 3.

Data inputs for transmission are made up of one or more files within the computational computer which may consist of any number of variable length records. The record length extends from a maximum of 4028 base ten 12-bit bytes to a minimum of one 12-bit byte. The maximum length is the limitation of a transmission block.

Output data for transmission is formatted as a transmission block in groups of 12-bit bytes. Each group consists of up to sixty-three intervals. Each interval consists of up to sixty-four 12-bit bytes plus control bytes. These control bytes are added for transmission control and are subsequently stripped by the receiving computer. A complete file may be transmitted as a number of groups. A group being sent may contain several records, but never contains more than one file. If a group contains more than one record, individual record pointers are included in the data section for identification.

Every message starts with five zero bytes followed by seven bytes containing a preselected start pattern. The next byte, termed the computer address code work (CAC) contains the address code and indicates the type of transmission (normal transmission, retransmission, or poll query), whether this group is the last of a file and the party of the file (odd or even). Figure 2 illustrates the CAC. The

COMPUTER ADDRESS CODE WORD (CAC)

11 10 9 8 7 6 5 4 3 2 1 0
ADDRESS BITS INDICATORS

BITS ARE SET ACCORDING TO THE STATION(S) RECEIVING

BITS: 11-6 COMPUTER ADDRESS BITS

5-

4 PARITY OF TRANSMISSION DATA

3 END OF FILE (EOF) INDICATOR IF SET

2

1 POLLING FOR REMOTE STATION TRANSMISSION

0 RETRANSMISSION INDICATOR IF SET

If bits 5-0 are the complement of bits 11-6, this indicates a polling query for the computer whose bit is set in bits 11-6.

Figure 2

next byte is the complement of the preceding byte. The complement is sent in this order for error detection since the CAC is not included in any checksum. For a group transmission or retransmission, the next byte is a zero byte, for hardware synchronization, followed by an interval number byte. The first data byte of the first interval of each group contains the sequence number and the indicator for acknowledgement of a good transmission. Data is now sent in the remaining sixty-three 12-bit bytes of this first interval (Ref. 4).

Error control is accomplished by an error detection process which depends on retransmission for correction. The basis for error detection is a checksum of each interval sent as a 12-bit byte immediately after the last data byte of the interval. In case of overflow, the checksum utilizes end around carry. The NEDN error detection/correction system advertised error is approximately zero (1 in 10 megabits of data for the circuit) since data is retransmitted until the received checksum is correct (Ref. 2).

Remaining data is now sent in intervals consisting of a zero byte, an interval number byte, 64 data bytes and a checksum byte.

All messages except the polling query end with a stop pattern which is the start pattern in reverse order. Figure 3 illustrates the standard message format.

The polling query consists of the start pattern and the station code. The acknowledgement (ACK) consists of the start pattern, station code, a good or bad ACK word, the

STANDARD MESSAGE FORMAT

```
0000 0000 0000
0000 0000 0000
0000 0000 0000
0000 0000 0000
S1
S2
S3
S4                START PATTERN
S5
S6
S7
CAC               RECEIVING COMPUTER ADDRESS CODE
CAC               COMPLEMENT OF CAC
0000 0000 0000    HARDWARE SYNCHRONIZATION BITS
0000 0000 0001    INTERVAL NUMBER
77xx              77=GOOD ACK INDICATOR,xx=SEQUENCE #
DATA

64th WORD AFTER INT #
CHECKSUM
0000 0000 0000
0000 0000 0002
DATA

64th WORD AFTER INT #    NOTE:  Record pointers
CHECKSUM                        are included in
S7                              the data if
S6                              required.
S5
S4                STOP PATTERN
S3
S2
S1
```

Figure 3

bad intervals, if any, and the stop pattern. The ACK word is the ACK indicator and sequence number as sent in the original message (77XX). A bad indicator is 66 followed by interval numbers to be retransmitted in 12-bit byte form. An ACK is sent in response to a polling query. The sending computer is responsible for the transmission until an ACK has been received for all intervals in a group from all receiving computers.

The Net Control Station (NCS) exercises circuit control and circuit discipline, which includes the responsibility of monitoring and reporting circuit quality. Naval communication circuit operating procedures are utilized as they pertain to operation of a dedicated digital/analog circuit. NAVWEASERCOMINST 2309.1 provides basic guidance concerning NEDN circuit operations.

Transmission coordination practices and policies are established to phase out voice requests for transmissions and rely on the automated system made possible by the computer software.

All transmissions must be preceded and identified by an appropriate catalog number to facilitate automation of processing. Standard files begin with an 48-bit record containing the applicable catalog number.

About 1% of the data output is considered classified because of its implications for ASW. This data, which can not be transmitted on the uncovered NEDN, along with all normal message traffic is transmitted to the Naval Telecommunications Center Monterey on a covered pony loop for insertion

in the AUTODIN system. This center is in the process of moving to the new building at FNWC. The move includes installation of a mode 1 AUTODIN terminal for direct access to the AUTODIN system (Ref. 5, p. 13). Future plans call for all NEDN data to be covered whether it is on AUTODIN or some other computer network.

APT has to do with the transmission of weather satellite photographs. Receive only earth stations located at Guam, Norfolk and Rota receive the APT signal from the satellites and transmit it "live" or store it on magnetic tape until another station requests that it be transmitted. London and Pearl Harbor have access to APT information from nearly colocated facilities. Some NEDN circuits are used to transmit analog APT information when they are not being used for digital transmission. NEDN lines are also used to relay 2400 HZ AM FAX transmissions of weather maps and documents.

Voice orderwire service is possible on the NEDN circuits for operator coordination, at present, but its use interrupts NEDN data or APT. This orderwire will be replaced by an 100 BPS teletype orderwire which may be superimposed on the NEDN data channel.

A planned upgrade in the NEDN software will do away with the broadcast mode of operation and cause all transmissions to be point-to-point asynchronous. Terminals will have a store and forward capability.

The FNWC computers do interface with the ARPA network. More on this subject will be discussed in the section on ARPANET.

The monthly cost of leasing the NEDN circuits is $39,228.62. These figures, obtained by telephone from NAVTELCOM on 17 October 1974, include the cost of the Rota-London link and are broken down as follows:

BETWEEN	PRIME-COORDINATOR	MONTHLY LEASE RATE
Monterey-Pearl	AT&T	$5,950.00
Pearl-Guam	HAWTELCO	9,293.05
Monterey-Norfolk	AT&T	1,820.96
Norfolk-Suitland	AT&T	659.71
Norfolk-Rota	ITTW	11,704.90
Rota-London	DCA EUR	9,800.00
TOTAL		$39,228.62

This amounts to an annual cost of $470,743.44 for the transmission lines alone of the system. The cost of other weather communication lines might double this figure but they are not considered part of the NEDN system.

Information concerning the amount of traffic on the NEDN circuits is taken from figures compiled by the NEDN support department dated 17 January 1974. The daily volume on the NEDN east and west lines was 50 MEGA-BPS per circuit at that time with peak hour traffic as high as 13 MEGA-BPS.

The need for data communications is determined by FNWC Monterey. This need is then translated into a formal Telecommunications Service Request (TSR) and forwarded

to COMNAVTELCOM. The current procedure is to specify the quality/capability of the service required by reference to telephone line quality. NAVTELCOM leases available long lines to fulfill the requirements of the request. The use of commercial leased lines rather than a military system is based on the federal government policy to rely on the private enterprise system for services except where it can be proven to be in the national interest to do otherwise. The DoD policy further strengthens this concept by requiring that commercial communications be utilized except where they are not available, where the cost would be significantly greater or where personnel training becomes a factor.

2. NIDN

The NIDN, controlled by Commander Naval Intelligence Command (COMNAVINTCOM), is a worldwide intelligence data network which supports the Ocean Surveillance Information System (OSIS). The NIDN system consists of low speed (75 BAUD) point-to-point teletype circuits terminated at intelligence sites: Naval Ocean Surveillance Information Center (NOSIC), Suitland; Fleet Ocean Surveillance Information Centers (FOSICS), Norfolk, London and Hawaii; and Fleet Ocean Surveillance Information Facilities (FOSIFS), Japan and Spain (Ref. 6, p. 23). Figure 4 illustrates the NIDN conceptually.

Inputs to the system are basic intelligence observations which are forwarded to the central information processing point at NOSIC Suitland. Outputs of the system

NAVAL INTELLIGENCE DATA NETWORK (REF 9)

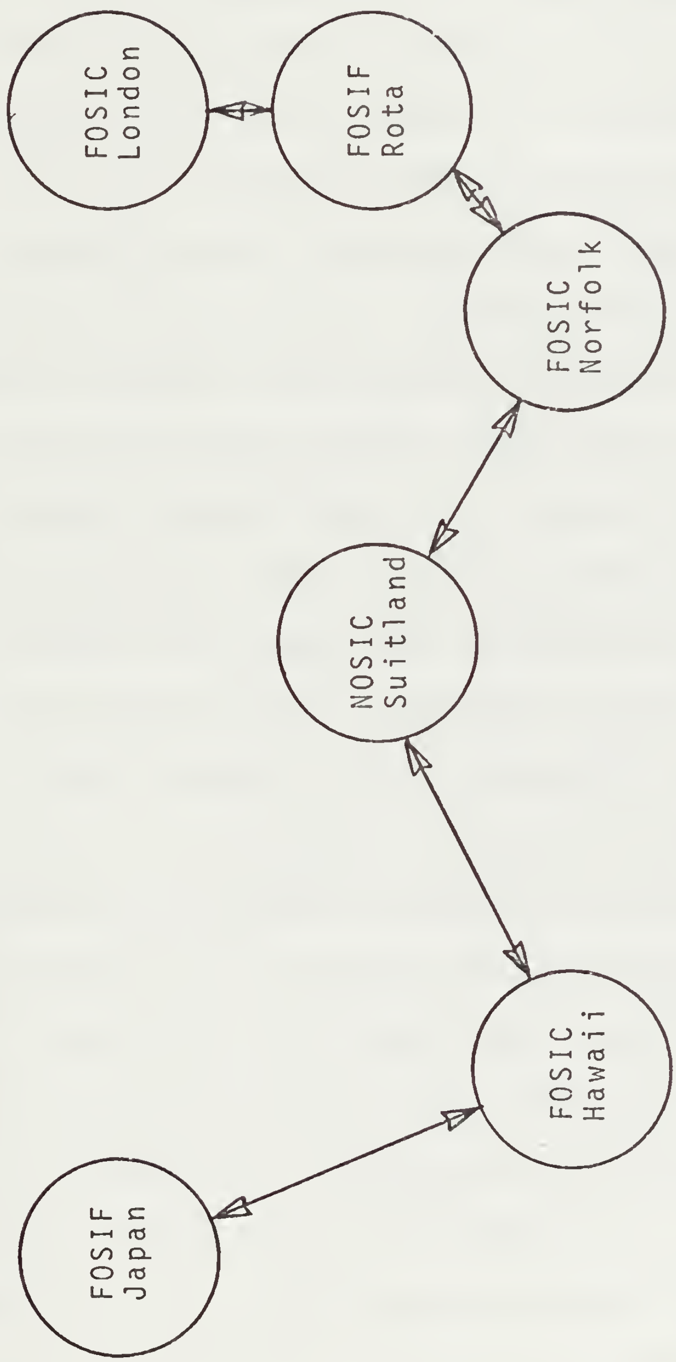


Figure 4

are evaluated intelligence which is transmitted back to the FOSICS and FOSIFS. These sites further process and disseminate the data to meet local support requirements.

An extensive upgrade to the existing NIDN will replace the teletype circuits with medium to high speed computer terminals which will operate in the point-to-point mode. (Ref. 7, p. 1) Point-to-point operation with store and forward capability will allow the line rates to be different on the various links. Funding restrictions forced the OSIS/NIDN to abandon the original distributed network concept and adopt the more limited capability of the centralized network design (Ref. 8, p. 120). The NIDN communication processors will format messages into blocks with address headers and pass them asynchronously until they reach their final destination. Message transfer will be limited to the east or west lines. No traffic will be passed from east to west except as relayed by NOSIC (Ref. 6, p. 23). Although the message transfer is asynchronous, synchronous transmission of the bit stream appearing at the line MODEMS is required. All NIDN data will be fully encrypted prior to its delivery for transmission and must be considered as a random bit stream in which any bit pattern or sequence is possible (Ref. 6, p. 50).

Many back up circuits are available for the NIDN data at the OSIS terminals. Of particular note is the DIN/DSSCS, Defense Intelligence Network/Defense Special Security Circuits, which could easily handle the NIDN traffic. NIDN

data would only increase the usage of this circuit 2% at most (Ref. 9). However, since it is shared vice dedicated circuit, there is some concern that it could become saturated and lower the NIDN through-put during periods of peak traffic (Ref. 6, p. 25).

3. NEDN/NIDN

In an attempt to save money and increase the intelligence flow to support the rapidly expanding OSIS, COMNAVINTCOM proposed to upgrade the NIDN to a medium speed digital data network and piggy-back segments of the new network on the existing NEDN circuits. A memorandum of agreement between COMNAVINTCOM and COMWEASERCOM was signed in 1969 establishing the NEDN/NIDN system. The common support functions of weather and intelligence were recognized as well as the parallel long-haul circuit requirements. The advantages to be realized by the NEDN would be increased data through-put by using more advanced MODEMS and enhanced circuit restoration priority because of time sensitive intelligence priorities (Ref. 10). NAVINTCOM was to provide the MODEMS and the multiplexing/demultiplexing equipment. NAVINTCOM was also to provide its own cryptographic devices for security and there would be no break-out of OSIS information at NEDN computer facilities. The Norfolk to Rota and Rota to London links are currently shared by each command.

As can be seen from an examination of Figures 1 and 2, several of the individual terminals of the two networks are located in reasonably close proximity. Sharing some of the more costly links should reduce the overall costs of the

two networks. Figure 5 illustrates the planned NEDN/NIDN combined networks.

The system of multiplexing the two networks is being developed by NELC under Naval Electronics System Command (NAVELEX) tasks. These tasks are in response to the specific operational requirement concerning OSIS, SOR 35-15 (Ref. 9). The communication terminals developed by NELC will allow the data circuits to be used in the synchronous mode. The individual users may be synchronous or asynchronous.

The NEDN/NIDN system as designed by NELC would meet the following general requirements:

1. The system shall be capable of terminating trunk lines of rates 2400, 3600, 4800, 7200, 9600, and 10,800 bits per second.
2. The system shall be capable of splitting these trunks into two subchannels (NEDN/NIDN) which share equally the overall transfer rate. Either channel may operate at rates of 1200, 2400, 3600, 4800, and 5400 BPS where this rate is less than or equal to 1/2 the trunk rate. Any circuit degradation will require equal overall data transfer rate reduction.
3. The system shall be capable of fully synchronous operation to permit encryption of data on the NIDN channel.
4. The NEDN channel shall support the transmission alternately of AM facsimile, automatic picture transmission (APT) pictures, or computerized weather data. A 100 BPS teletype orderwire and link synchronization characters shall be superimposed on this channel. Periodic interruption of the NEDN computer clock is permissible on the channel to allow insertion of the teletype and sync subchannels.
5. The NEDN computer I/O channel shall be capable of interconnection with other channels of comparable data rates to allow operation of the NEDN computers in the present half duplex broadcast mode configuration. The channel shall be capable of future reconversion to point to point only operation when the NEDN upgrades to full duplex operation. The APT,

NEDN/NIDN COMBINED NETWORKS (REF 6 P. 26)

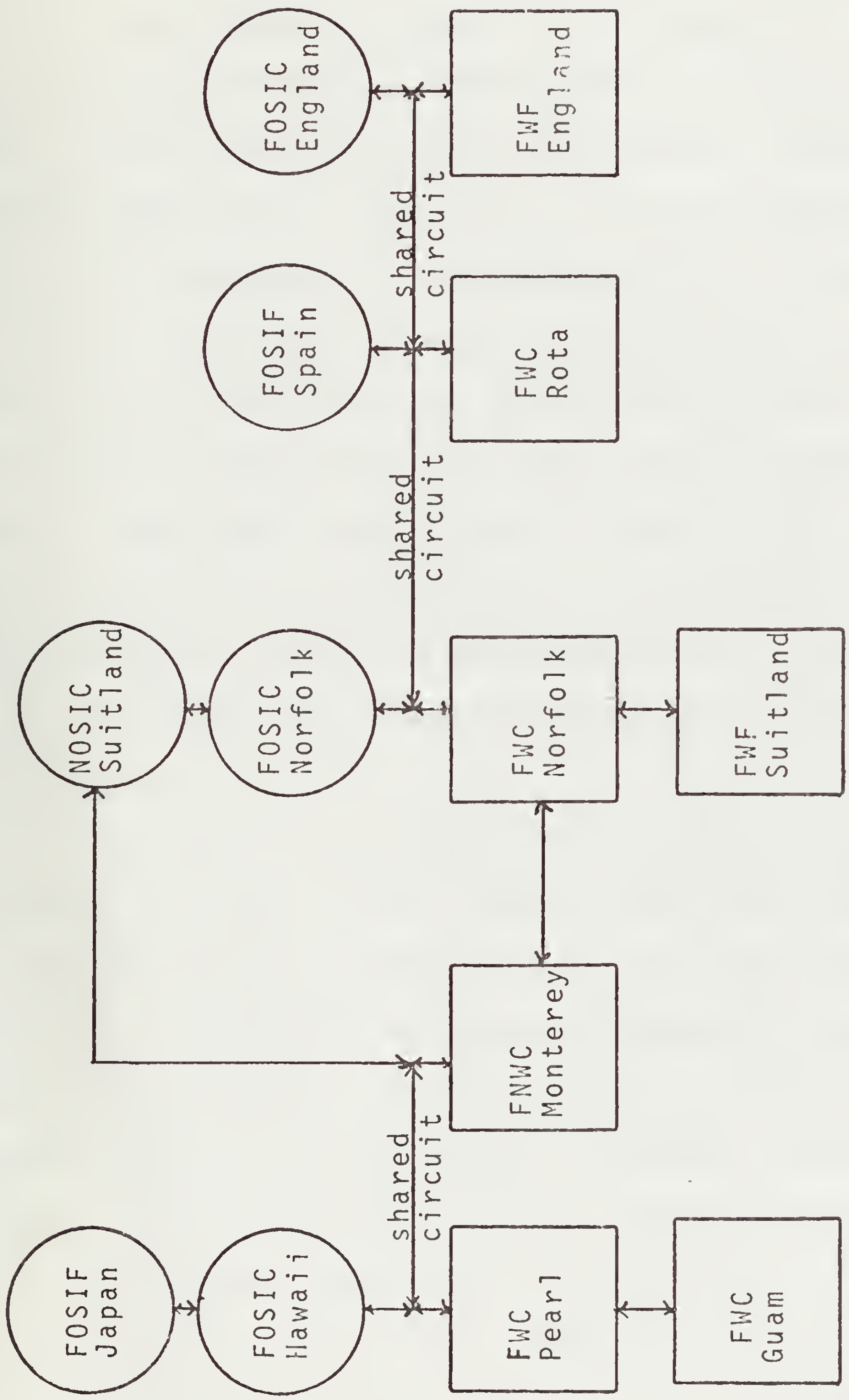


Figure 5

> facsimile, and teletype channels shall operate only in a point to point configuration (Ref. 6, p. 39).

The NEDN/NIDN communication terminal provides the means by which NAVWEASER and NAVINTCOM can share designated links. "The NEDN/NIDN transmission system, including all software and hardware subsystems, is unclassified." (Ref. 6, p. 68) Data appearing on the NEDN circuits is unclassified and data on the NIDN circuits is covered when it enters the terminals for transmission. Information in this section of the thesis is presented as though it were in effect. However, the reader should bear in mind the fact that the system is still in the planning and development stage. Some terminals are in place and functioning, but, it is possible for the final system to be quite different from that which is stated here.

Figure 6 illustrates the functional layout of the terminal. The heart of the terminal will be a Digital Equipment Corporation computer, the programmed data processor (PDP) 8/E. The PDP-8/E is a second generation computer, originally marketed in 1965. The main function of this computer will be to time division multiplex the two data streams. It is particularly suited for this function since it contains a data channel multiplexor which provides direct memory address for up to seven external devices. (Ref. 11, p. 366) In addition, it has a very flexible input/output section to enable it to interface with special equipment. This flexibility is important in real time data processing and

TERMINAL HARDWARE LAYOUT (REF 12 P. 26)

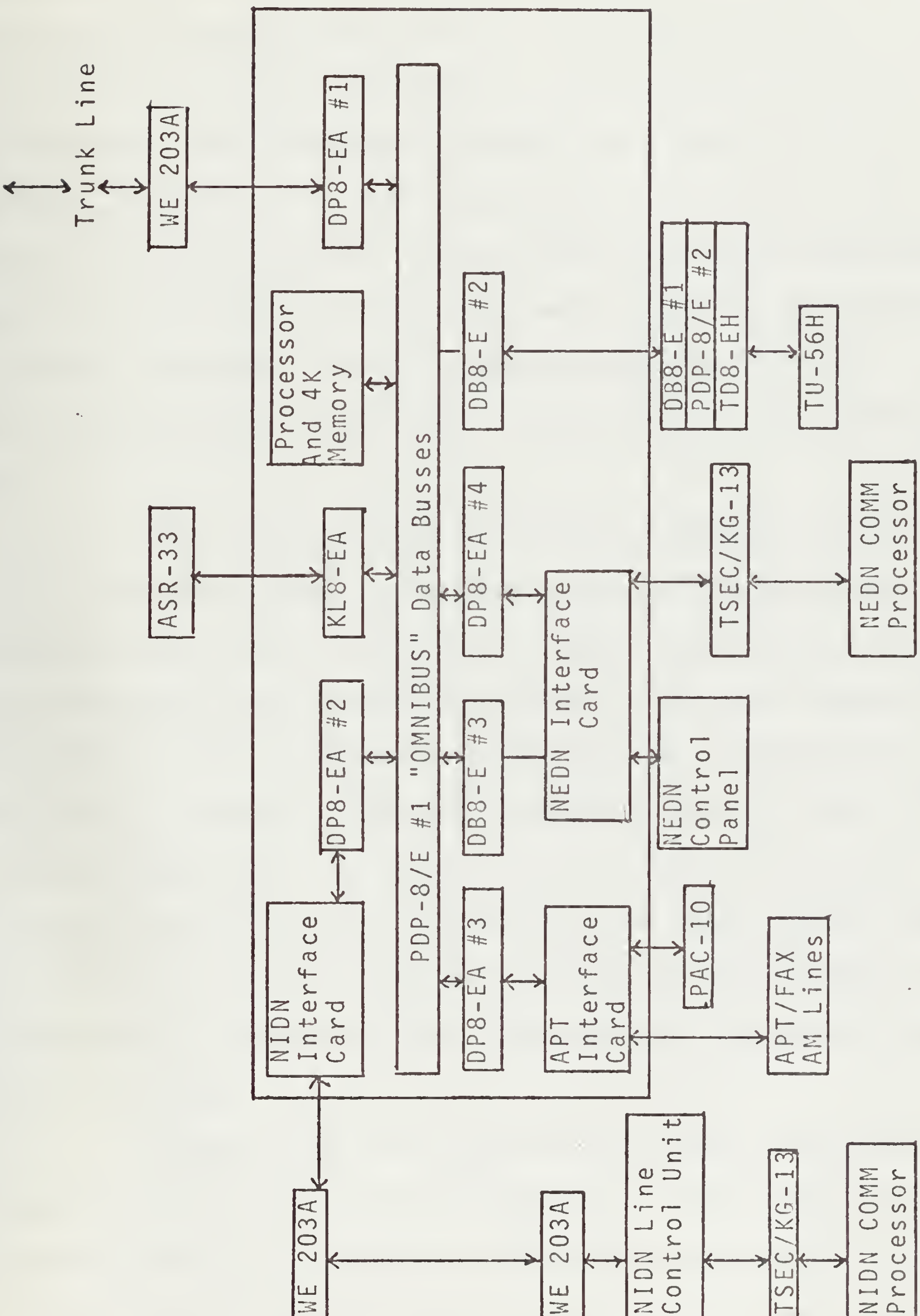


Figure 6

control environments. Commercial multiplexors other than computers are available but they would not allow any change in synchronization format (Ref. 7, p. 20) or control. More flexibility in the multiplexing function can be provided by a computer. This particular machine was picked for this purpose because it had previously been determined to use an PDP-8/E for APT storage. System maintenance and training would be simplified by using the same model for two different purposes, however, primary consideration was that the multiplexor would have a readily available back-up. (Ref 7, p. 22)

The computer used for this function is referred to in the available NELC literature as a multiplexor, but it performs more as a concentrator, since it performs the work of transhipment and temporary storage as well as control. The PDP-8/E mini-computer is programmed to control and monitor the system; supervise peripheral units; buffer the incoming NIDN data; set up the channel for transmission; interface NEDN, teletype, NIDN, FAX, and APT; perform serial to parallel conversion and rate buffering; and multiplex two independent full duplex data channels onto one trunk line. (Ref 7, p. 23)

A system has been devised by NELC around peripheral equipment to digitize APT or FAX data. Digitizing the data allows speeding up the rate of transmission when using the high data rate channels and provides improved quality pictures. The AM signal is demodulated, sampled and then compressed using

a technique called source approximation encoding and decoding (SAED). (Ref 7, p. 10) A DACOM, INC. PAC-10 data compander accomplishes this function, converting the AM video signals to a serial data stream. (Ref 12, p. 9) The second PDP-8/E computer is used primarily to store and retrieve the digitized pictures. (Ref 7, p. 9-19)

The interface cards function principally as electrical interface line handlers by accepting the data from the line and setting the proper data voltage levels for the computer. Three interface cards, manufactured by NELC, are planned for each terminal. (Ref 12, p. 4) The NIDN interface card is the simplest, functioning as stated above. The APT interface card performs additional functions. It modulates/demodulates the AM FAX and APT data, routes it to and from the data compander and then to the main computer. The NEDN interface card provides the connection for the NEDN EDP data and the NEDN control panel.

The synchronous interface modules are DP 8 status and control registers. They function principally as line level adapters, converting the line serial bit stream to parallel 8-bit words, or vice versa depending on the direction of flow. Data within the main computer is handled by transferring these words in parallel. The DP 8's have a small storage capacity which is used for temporary storage during transfer of data, but all named buffers are located in main memory. There are four DEC DP 8's planned for each terminal. (Ref 12, p. 65) These will provide trunk MODEM control, NIDN channel control, NEDN channel control and APT serial interface.

There are three DEC DB8-E's per terminal. Two perform as interprocessor buffers, controlling data transfer between the two PDP-8/E computers. The third functions as an I/O interface for the NEDN control panel.

The tape control card, a DEC manufactured TD8-EH, controls the tape transport (TU-56H) providing an interface between the second PDP-8/E and magnetic tape used for bulk storage of digitized APT data.

The KL8-EA teletype control card provides the interface between the teletype model 33 ASR and the main computer. The teletype uses an 8 bit modified American Standard Code for Information Interchange (ASCII) code. The control card reads the asynchronous serial information, converts it to parallel and transfers it to or from main memory, one word at a time. Teletype information is the orderwire for the system providing coordination between terminals.

The NEDN control panel provides an operator interface with the terminal, allowing mode changes and input control. (Ref 13, p. 29)

Western Electric 203A MODEMS are used on the main trunk line. Data is fed to or from these MODEMS by DP8-EA #1. This unit transfers data from the trunk line MODEM to the trunk receive buffer (LRBUFF) and data to the trunk MODEM from the trunk transmit buffer (LXBUFF). The word transfer rate is set at installation. DP8-EA #1 also performs line MODEM control and line monitor functions.

The main PDP-8/E "OMNIBUS" data bus can be considered as a super sink, in one sense, since it accepts data from a number of sources. NIDN data is formatted in the NIDN communication processor, encrypted using an TSEC/KG-13 and fed to the NIDN line control unit. Since the NIDN facility could be several miles from the NEDN facility, provisions are made to install Western Electric 203A MODEMS to modulate and demodulate the signal for this transmission if necessary. The use of these MODEMS depends on the distance to be covered and the quality of the line. Upon arrival at the terminal, the signal is fed through the NIDN interface card to DP8 #2 status and control register. Data flows from this register to the NIDN transmit buffer (IXBUFF) and then to the trunk transmit buffer. Received data would flow from the trunk receive buffer to the NIDN receive buffer (IRBUFF) thence in reverse on the path discussed. (Ref 12, p. 6-11)

NEDN data is formatted in the NEDN communication processor, encrypted using an TSEC/KG-13 and fed through the NEDN interface card to DP8 #4. Data flows from this register to the NEDN transmit buffer (EXBUFF) and then to the trunk transmit buffer. Received data would flow from the trunk receive buffer to the NEDN receive buffer (ERBUFF), then to DP8 #4 and back through the indicated path.

The 100 BPS teletype orderwire channel can be superimposed on the NEDN data channel at any time. The method is covered later in this section. Orderwire data is passed from the teletype unit (ASR 33) through the KL8-EA

to the teletype transmit buffer (XTTYWD) and then to the trunk transmit buffer. Received orderwire data comes from the trunk receive buffer to the teletype receive buffer (RTTYWD) and then back to the teletype unit. The teletype buffers only hold one computer word. They function as printer and keyboard holding buffers. When the orderwire is used, it will reduce the NEDN through-put on the trunk line. (Ref 12, p. 4) Teletype orderwire data will not be encrypted. (Ref 14)

There are two ways to send APT information. APT or FAX replaces NEDN EDP data on the NEDN channel when sent. APT is discussed here as FAX transfer would be similar. As mentioned previously, APT can be sent live (on-line) or from tape (off-line). In the case of live APT, PDP-8/E #2, the tape controller, is bypassed. APT comes in from the receiver via the APT interface card, the PAC-10, and thence through DP8-EA #3 to the single APT buffer (APTBUFF). It is sent from here to the trunk transmit buffer and thence to the line. On-line APT data coming to the terminal would be routed back to the single APT buffer. This single buffer limits live transmission to half-duplex operation. For stored APT, the second computer, under the direction of the NEDN control panel, reformats the bit stream, buffers the data and records it on an DEC TU-56H tape unit which is compatible with the controller. Routines will exist within the controller to receive and record APT from a local pass or from a remote terminal. This data can then be retrieved and either routed for digital to analog

conversion and picture development or transmitted to another remote terminal. Either operation, live or tape, will be point to point only.

Live APT requires the full bandwidth of the NEDN portion of the channel, negating the use of the NEDN teletype orderwire during this mode of operation. Stored APT is extensively buffered and transferred at a different rate, hence the orderwire can be added to the channel during this operation. Neither FAX nor APT will be covered. (Ref 14)

The software programs are written to allow NEDN/NIDN to share dedicated voice-grade, long-line circuits. The system was sold on the basis of equal sharing, but, as seen in this section, the bit rate required for terminal synchronization comes out of the NEDN portion of the channel. Any trunk rate can be used up to 10,800 BPS. Current limitation is 9600 BPS, allowing the individual user up to 4800 BPS on designated links. The TSEC/KG-13 is compatible with this 4800 BPS rate.

The software package for the two PDP-8/E's is written in machine language. It will be written on magnetic tape or paper tape for alternate loading. The data rates are set at system start up by a computer dialog with the operator. Program operation is automatic, controlled by the NEDN control panel and the NIDN control unit.

Hardware converts all bit streams to 8-bit words. These are used for multiplex and storage functions in the main computer. Trunk line data format is illustrated in

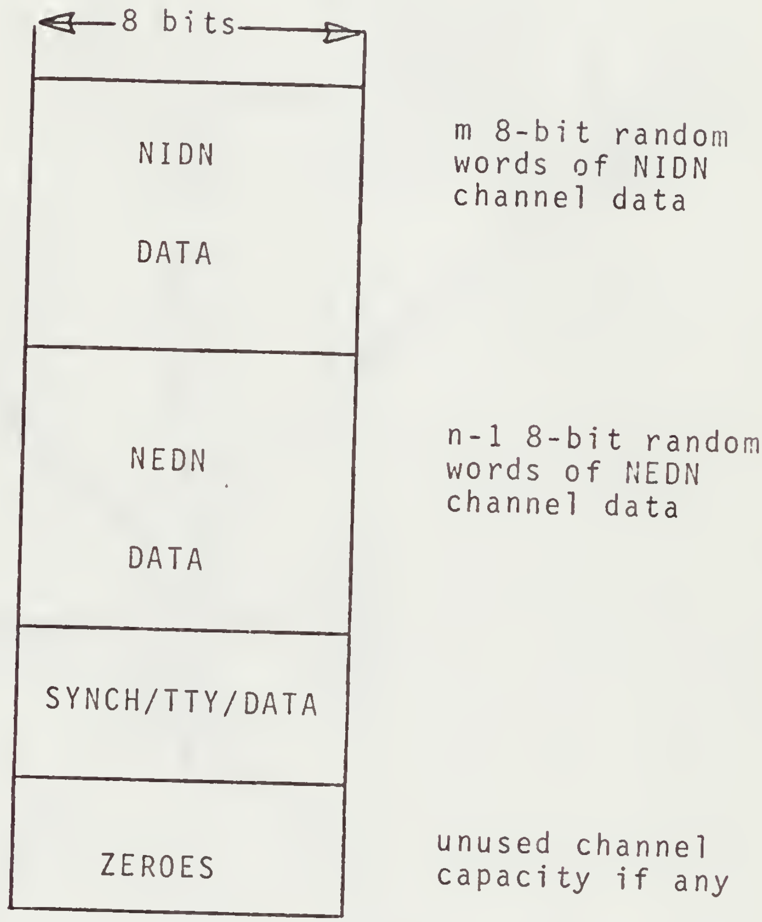
Figure 7. The sub buffer lengths depend on the user's data rate. Two subroutines develop the output buffers for actual multiplexing.

The main program causes the system to run through the subroutines. Start initializes all devices and software. Retrain sets up the system buffers and synchronizes the MODEMS on the trunk line. Once this is done, the computer goes into a SYNCH cycle. SYNCUP accomplishes multiplexor line SYNCH on the trunk circuit, after which MUX takes over. MUX is the basic program for system control during multiplexor operations. SXMUX/SRMUX subroutines perform actual multiplexing and demultiplexing operations. The sub buffer contents are transferred to and from the trunk buffers during these subroutines. When the trunk buffer is full as illustrated, its contents are transmitted. A synchronizing character is added to the contents of every 255th buffer. If the orderwire is being used, one teletype character is sent with every sixth buffer. The NEDN clock is inhibited for one word during these transfers. Any unused portion of the total buffer is filled with zeros if the NEDN or NIDN channels are less than 1/2 the trunk rate. (Ref 13, p. 32-44)

4. <u>AWN</u>

The Air Force Automated Weather Network (AWN) is a worldwide weather network which has been operational since 1965. Presently, the hub of the system is located at Carswell AFB, Texas. Figure 8 illustrates the AWN. The AWN consists of high speed (2400 BPS) and low speed (radioteletype) circuits to and from intercept and distribution

NEDN/NIDN TRUNK LINE DATA FORMAT (REF 13 P. 19)



USER DATA RATE	SUB BUFFER LENGTH m or n
1200 bps	2 words
1800 bps	3 words
2400 bps	4 words
3600 bps	6 words
4800 bps	8 words
5400 bps	9 words

Figure 7

AUTOMATED WEATHER NETWORK (AWN) (REF 16)

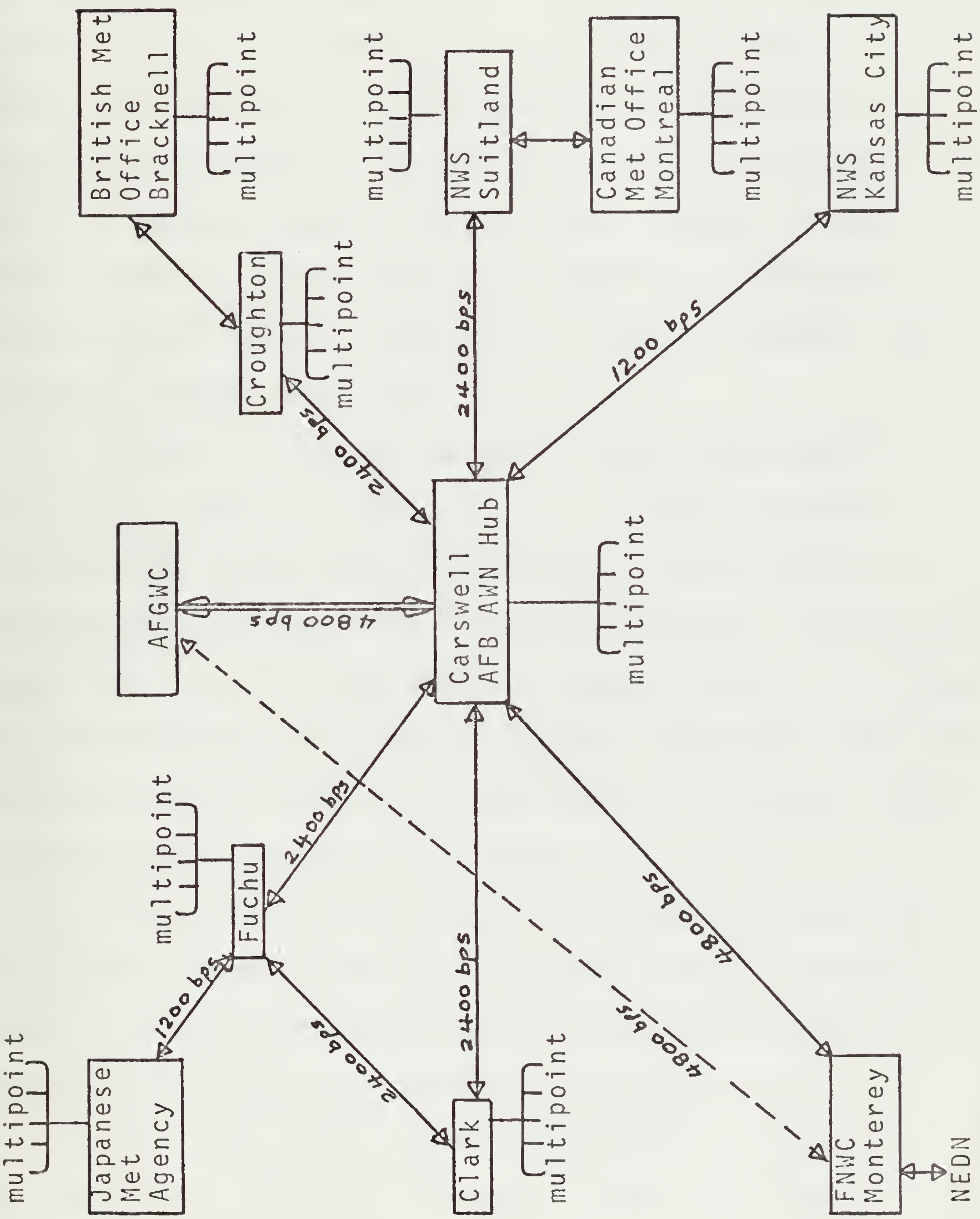


Figure 8

points. The primary mission of the AWN is to acquire and transport SINO Soviet intercepted weather data to the Air Force Global Weather Center (AFGWC) located at Offutt AFB, Nebraska as rapidly as possible. The data is collected at Carswell and sent to Offutt by high speed link (4800 BPS). The secondary mission of the AWN is to acquire, process and distribute digital weather data for DoD agencies. Main computer sites to accomplish these functions are located at Carswell, Fuchu, Japan, Clark AFB in the Philippines, and Croughton, England. (Ref 15)

Inputs to the system are raw and intercepted weather data which is transmitted to the main computer sites for high speed relay to Carswell. The majority of information (31%) comes from Croughton, England. The second largest data source is the National Weather Service, Suitland which provides 22% of the total. Lesser amounts of data are provided by Fuchu, Clark, FAA, Pan American Airlines, Miami Hurricane Center and others. (Ref 15)

The AFGWC is the biggest "customer" of the AWN, receiving 26% of the total daily output. Other customers include the National Weather Service and FNWC Monterey both of which receive 12% of the daily output. (Ref 15)

The AWN provides some low speed switching of weather data for the Navy. Several 75 BAUD circuits from Carswell to Navy facilities, such as, Norfolk, Alameda and Bermuda are maintained. Carswell switches the data from digital to teletype.

The most interesting aspect of the AWN, at least to the telecommunication systems management student, is the division of responsibilities between the Air Force Communication Service (AFCS) and the Air Weather Service (AWS), an examination of the AWN function at Carswell AFB will illustrate this aspect. Elements of the AFCS are responsible for communication programming, computer operations, technical control, housekeeping, power, teletype/MODEM maintenance and management of traffic, circuitry and intercept. The AWS detachment is responsible for the acquisition, processing and distribution of digital environmental data for DoD agencies. (Ref 15)

Carswell has a most realistic approach to the power supply problem in that commercial sources of power are considered tertiary. Primary power is supplied by turbine generators and secondary power by diesel generators. (Ref 15)

The combination of good management practices results in an impressive total system reliability. According to the brief given at Naval Postgraduate School, Monterey, in the worst month, system reliability was 98.8 percent. The reasons given for this high figure were as follows: there is complete hardware redundancy. Back-up power is available as described earlier. Adequate time is set aside for testing. A rigid schedule is followed for all software changes. (Ref 15)

Although not part of the AWN, other communication facilities at Offutt allow the AFGWC computers to interface with AUTODIN, the ARPANET, the Astrogeophysical Teletype

Net (ATN), and the DSSCS. Direct service is provided to the National Military Command Center. (Ref 16)

The Defense Meteorological Satellites dump to receivers located at Loring AFB in Maine and Fairchild AFB in Washington State. This data is then sent by commercial satellite to the AFGWC at Offutt. (Ref 17) Information is provided from the National Environmental Satellite System by way of land line from Suitland.

The Naval Weather Service interfaces with the AWN primarily by way of high speed land lines between FNWC Monterey and Carswell. The interface with the AFGWC is by way of one high speed land line between FNWC and Offutt. These lines are neither part of the AWN nor the NEDN. The cost of the primary and back-up lines to Carswell from FNWC is $1,692.43 per month. This information was provided by telephone conversation with NAVTELCOM. The cost of the one line between FNWC and Offutt is $1,274.00 per month. (Ref 2)

5. <u>ARPANET</u>

The ARPA Network stemmed from a number of government-sponsored research projects during the 1960's. Dr. Lawrence G. Roberts of the Advanced Research Projects Agency is credited with its beginning. (Ref 18, p. 569) Initial experiments were carried out in 1966 to test the philosophy of a cooperative network of resource sharing computers. (Ref 19, p. 543) Based on their research, ARPA provided the plan for the network. The data circuits were

designed and implemented by the American Telephone and Telegraph Company. The Network Analysis Corporation performed initial analysis of capacity and designed the initial network topology. Bolt, Beranek and Newman, Inc., (BBN) developed the data transmission system between the message processors (Ref 20, p. 10). The first phase of ARPANET, begun in September of 1969, connected ARPA contractors who were working in the areas of computer system architecture, information system design, information handling, computer augmented problem solving, intelligent systems and computer networks. The second phase added the research disciplines of behaviorial science, climate dynamics and seismology. (Ref 19, p. 548) The original network connected 14 sites. Today, the network stretches from Hawaii to Europe and encompasses approximately 40 connection nodes and over 50 computer and research installations. (Ref 21, p. 56) Figure 9 illustrates the geographic layout of the ARPANET as of January 1974. Operation of the ARPANET is managed by the range measurement laboratory of Patrick Air Force Base. (Ref 8, p. 34) It has been confirmed by telephone conversations with the ARPA information systems office that the Defense Communication Agency will take over management of ARPANET as of 1 July 1975.

The development of ARPANET makes resource sharing between computers a reality and will be studied in two segments. The first aspect studied will be the computational computers at the research sites and the second

ARPANET, JANUARY 1974 (REF 22 P. 14)

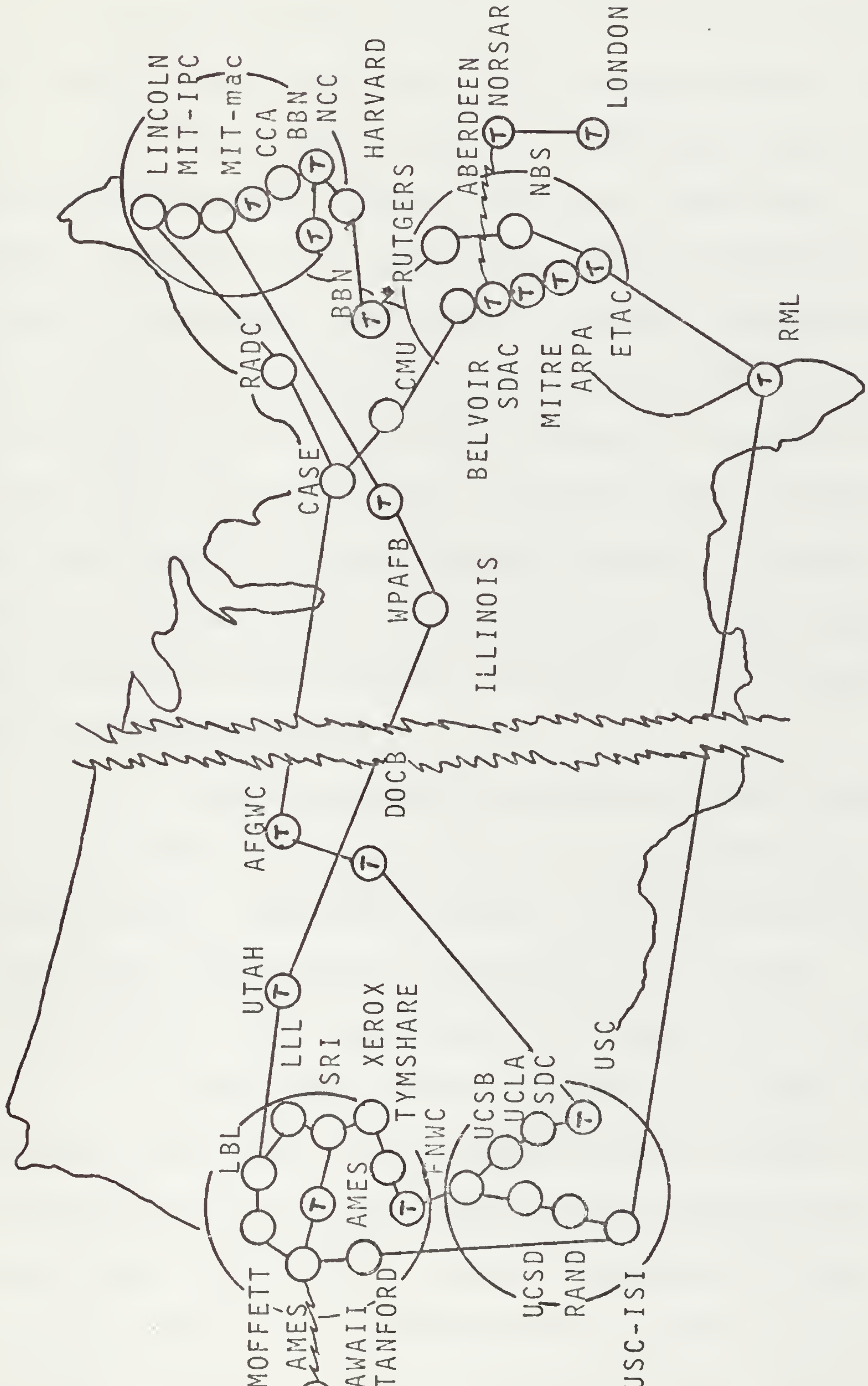


Figure 9

will be the communications SUBNET with emphasis placed on the communication aspects of the network.

Many different makes and models of computational computers are located at the various research centers within the ARPANET. These computers are widely dissimilar in that they may use different speeds and word sizes, represent characters in a different fashion and manage file and operating systems in a variety of ways. The computers range from a large number of Digital Equipment Corporation PDP-10 and PDP-11's to the massive ILLIAC IV complex at NASA-Ames, all are termed host computers. The Control Data Corporation 6500's at Fleet Numerical Weather Central, Monterey are host computers in this network. Host computers at each node may offer services to remote users or provide access for local terminals.

Interface message processors (IMP's) provide the means by which this wide variety of computers can intercommunicate. Each IMP converts the characteristics of the individual host which is connected to it to the characteristics of the communications SUBNET and vice versa.

IMP's connected by 50 KBPS full-duplex data transmission lines make up the communications SUBNET. The IMP's installed at each node insulate the computational computers from communication related handling problems, such as, routing, buffering, synchronization, error control and reliability. Honeywell DDP-516 computers were chosen as the standard IMP for the SUBNET. Initial use of a standard

computer resulted in a homogeneous communications network. The DDP-516 uses a 16-bit word length, has a 12K memory with space for additional 4K memory and contains a set of 16 multiplexed channels. The IMP, a relatively small message processor, provides special modular interfaces between itself, phone line MODEMS and host computers. (Ref 23, p. 557) There are one to four host computers connected to each IMP.

A later interface development was the terminal interface processor (TIP) which provides direct console access to the network. A TIP is an enhanced IMP in that it acts as an IMP as well as a simple host. (Ref 24, p. 6) The TIP has sufficient logic to accomplish its own interfacing. The node at Monterey is a TIP interfacing with the network through 50 KBPS circuits to the University of California at Santa Barbara and the Tymshare Corporation in Cupertino. (Ref 25) The local CDC 6500 makes up the 1000 bit packets and sends them through the CDC 3200 to the best of the two available circuits. In this way, weather fields containing up to 10 megabits of data have been sent to NASA-Ames from FNWC. (ref 2)

The SUBNET is a fully distributed network utilizing a store and forward or delay-engineered (Ref 24, p. 5) packet switching system. ARPA investigated fully interconnected point to point leased line, circuit switching and message switching networks. Their research indicated that the packet switching approach provided the greatest flexibility, highest effective bandwidth and lowest cost by

achieving the highest line utilization. (Ref 19, p. 545) At least two communication paths exist at every node. This topology enhances message handling, reliability, recovery and flexibility by providing redundant transmission paths.

Communications on the SUBNET are governed by protocols. Protocols are defined in reference 26 as follows:

> "When we have two processes facing each other across some communication link, the protocol is the set of their agreements on the format and relative timing of messages to be exchanged. When we speak of a protocol, there is usually an important goal to be fulfilled. Although any set of agreements between cooperating (i.e., communicating) processes is a protocol, the protocols of interest are those which are constructed for general application by a large population of processes in solving a large class of problems." (Ref 26, p. 271)

Protocols in the ARPANET are layered and spoken of as high or low level. Three lower level software protocols support the user-level communications interface for ARPANET. (Ref 26, p. 271)

The lowest level software protocol, sometimes referred to as first level, maintains IMP to IMP communications. This protocol causes the individual packet to be sent node to node through the network to its destination using alternate routing procedures to find the best path. Each node accepts the packet from the transmitting node, checks it for errors and sends it on to the next node. The packet is stored at a node until an acknowledgement is received from the next node. Storing allows the packet to be retransmitted if a transmission error is detected. Individual packets may

travel on separate paths through the network and possibly could reach the destination IMP out of sequence. The final receiving IMP assembles the packets into the proper sequence for the message to the destination host. Because of the rapid response time of the SUBNET, these procedures are transparent to the host computers. (Ref 23, p. 554)

The next higher level protocol, sometimes referred to as second level, governs host to IMP communications over dedicated leased lines termed links. These links can be of any capacity compatible with the data transfer rate. A handshaking procedure is used on these links to pass messages asynchronously. The maximum message size is limited to 8095 bits because of buffering restrictions. (Ref 23, p. 553) The beginning of this message is a 32-bit leader containing address and control data. The data in a message may take any form so long as the leader is recognizable by the IMP. The IMP accepts the message from the host, breaks it up into 1000 bit packets and adds a header to each packet for network control. This protocol, in effect, creates a virtual communication path between hosts. (Ref 26, p. 271)

The next highest level protocol, sometimes referred to as third level, governs host to host communications. This protocol "is the set of rules whereby hosts construct and maintain communication between processes (user jobs) running on remote computers." (Ref 26, p. 272)

High level protocols control user processes, such as, use of remote interactive systems, file transfer, and remote job entry. (Ref 26)

The SUBNET is guarded against failures by a number of procedures. Special packets are exchanged between IMP's when no regular transmissions are taking place. A line is considered dead when transmissions in either direction have not taken place for 2.5 seconds. Tables in the routing algorithm are then updated and packets are rerouted around the dead line. (Ref 23, p. 555) If a packet is somehow lost or delayed within the network so that the message at the destination IMP cannot be reassembled within 15 seconds, the source IMP and host are notified and the procedure must begin again. (Ref 23, p. 556) "In the event of detected software failures, cooperating programs permit a subnetwork computer to be reloaded from one of its neighbors." (Ref 20, p. 16)

In addition to processing packets, the operational program for the SUBNET monitors network status, gathers statistics and performs on-line testing. (Ref 23, p. 559) Various subroutines accomplish these tasks.

The most recent cost data available is taken from an ARPA memorandum of January 1972. Initial costs depend on the type of terminal desired. Installation of an IMP, which could include one host standard interface and the first year maintenance, costs $45,000. A TIP would cost $92,000. Recurring costs for maintenance are $5,000 per year for an IMP and $7,000 per year for a TIP. At one time, ARPA proposed that the communications cost per node be $16,500 per year plus $0.30 per kilopacket in excess of 4500 kilopackets in a single month. (Ref 27) In a personal

telephone call, Professor Cerf at Stanford University stated that all costs were "mildly unresolved" and that no charges were presently made by ARPA as proposed. Professor Sher stated in reference 21 that the University of Illinois network communications and access costs amount to about $7,000 per month, but he did not give a breakdown for this figure. (Ref 21, p. 58)

Mr. S.T. Walker, an ARPA program manager, explained by telephone on 13 May 1975 the projected plan for billing customers after DCA takes control of ARPANET. He stated that the total cost of the network per year will be divided by the total number of hosts to obtain the cost per host per year. The projected cost for 1975 is approximately $35,000.00 per host. The DECCO is to bill customers on a monthly basis. Using this procedure, the cost to the individual user will be reduced as new users join the network. Mr. Walker also stated that DCA officials are enthusiastic about new customers joining the network.

B. WEATHER SERVICE COSTS

The total obligational authority granted for fiscal year 1975 to the Navy for weather and oceanography is as follows:

PROGRAM III

ELEMENT CODES	MISSION	SPONSOR	AMOUNT
3 51 11 N	Weather Service	OP-094	$32,003,000
3 51 12 N	Oceanography	OCEANAV	34,359,000
3 51 17 N	WeaServ Commun	OP-094	251,000

(Ref 28)

It is not clear to the author what area the last item covers. The annual cost of the NEDN transmission lines alone is $470,743.44. Costs of other weather communications lines, such as FNWC-Offutt ($1274 per month), could possibly double this figure. It appears that the Naval Telecommunications System (NTS) funds most of the weather service communication costs and that the figure quoted above is for incidental expenses. A "complete" computer run of weather circuits as recorded on the DECCO tapes has been obtained from NAVTELCOM. This compilation is classified so specifics will not be discussed in this study, however, some general comments should be made. The computer print-out is not complete and in many cases the commercial circuit designator is not available and no cost is given. It is not exactly clear to the author why the listing is classified since the information is available from commercial telephone companies nor why it does not include all the weather circuits. It leads one to believe that the Navy does not know what it costs to transmit weather data and that they do not want anyone else to find out.

Funding for the hardware and operation of the Navy's receipt of environmental satellite data is not available. Additional funds are being spent in this area to procure shipboard environmental terminals (SET's) for direct readout of environmental satellite data. A question for future detailed analysis is how will the SET's affect the requirements for the weather channel of the fleet multiplexed broadcasts?

No figures are available for the Air Force Weather budget. A fair assumption might be that the funding is at least as much for the Air Force as it is for the Navy.

A recent high level decision by the Navy will merge the meteorological and oceanographic communities into a single service. This should have an effect on the total budget requirements, but again, information is not available in this area.

The National Oceanic and Atmospheric Administration is funded through the Commerce Department. The 1975 estimated operating cost for direct programs is listed below. A breakdown by agency, such as the National Weather Service was not given in the budget.

PROGRAM	1975 ESTIMATED FINANCING
Basic Environmental Services	$103,117,000
Environmental Satellite Services	61,475,000
Public Forecast and Warning Services	47,875,000
Specialized Environmental Services	28,353,000
Environmental Data & Information Serv.	11,572,000
Global Monitoring of Climatic Change	1,112,000
Weather Modification	4,725,000
International Projects	9,148,000
Retired Pay, Commissioned Officers	1,818,000
Executive Direction & Administration	20,527,000
Total Operating Costs	$426,487,000

(Ref 29, p. 243)

C. ANALYSIS

There are several recognizable problem areas uncovered by this study. Some of the problems discussed might be categorized as Navy problems and could be solved in-house. In the office of CNO, The Director, Command and Support Programs, RADM Boyes controls weather, communications, intelligence and reconnaissance/ocean surveillance. A new office has been set up called the Naval Telecommunications System Architect which RADM Boyes feels should funnel "previous parochial interests into the general flume of a system which will mean the best and the most for the least cost." (Ref 30, p. 7) That statement sets the tone for this analysis, which is concerned soley with the communications aspect of the NEDN without regard to the use, need or application of the data transmitted.

1. Need for Communication System Specialists

The Naval Weather Service has done a fine job designing, developing and running the NEDN system, however, this has been accomplished by having meteorologists heavily envolved in data communications work. In this case, the user understands his own requirements, but is not necessarily concerned with the overall Naval Telecommunications Systems (NTS) plan. Communications are simply being procured in response to telecommunications service requests (TSR's) and the requirements are not being incorporated into any particular system. Transmission of data is a communication function. The weather service should only state the require-

ments to transfer data from point A to point B at a desired rate. Naval communications should take over from this point. Communication system specialists who can design, analyze or recommend a system in response to the user requirements should then examine the request. They should be responsible for blending the requirement into the overall NTS plan. Communication system specialists should be responsible for management of the links, including line quality control by monitoring, testing for conditioning, installation of equalizing equipment if required and digital test equipment for testing through-put as well as the procurement function. A similar division of responsibility could exist between the Naval Weather Service and the NEDN controlled by the NTS as exists between the AFGWC and the AWN. Once this is accomplished, the communicators should turn their attention toward minimizing the cost of the communication links.

While being responsible for the procurement function, NAVTELCOM should not be doing the actual leasing of these transmission lines. The Defense Communications Agency has the expressed charter to integrate and manage long-haul, point-to-point communications assets of all the services and has established the Defense Commercial Communications Office (DECCO) for the purpose of procuring communications outside the Defense Department. For better overall management, this Navy communication requirement should be passed to the DECCO to take advantage of the procurement expertise residing in this office. For example,

DECCO orders private lines under the TELPAK Tariff at greatly reduced rates over the non-TELPAK mileage rate. (Ref 31, p. 6) A more cost effective leasing option would naturally be available to the volume dealer at the defense level.

Throughout the research for the NEDN/NIDN section of this study, no communication requirements or planning by NAVTELCOM was in evidence. NAVTELCOM was never mentioned in any literature or conversation. Shouldn't NAVTELCOM have something to do with the planning for elaborate communication terminals and systems? The answer could well be no, because NAVTELCOM does not control the communication links, NAVWEASER does through the NEDN support department at Monterey. Again, the author feels that communication system specialists should be controlling this type of planning. The principles of management are not being used in this system.

2. NEDN

The NEDN system is capable of complete full duplex automatic data exchange and processing and four wire circuits are leased for this purpose. However, the system operates in a half duplex mode because of the necessity to broadcast data to more than one station. Full duplex lines for a computer network may be economical even though not fully utilized as they do save MODEM turn around time. Circuit discipline is maintained by the CDC 3200 software which requires both stations on either the east or west line to be on line for transmission. The broadcast system further

requires that a polling query be sent to solicit acknowledgement for the transmission. This requirement to poll for an acknowledgement of a transmission is a minor time consuming process. The total proposed NEDN/NIDN system is required to be more complex because the current NEDN software utilizes this broadcast mode. The broadcast mode of operation places the limitation on the system of operating at the lowest data rate of any link and causes the intermediate terminals to be more elaborate. Future plans for the NEDN do include rewriting the software programs to use the point-to-point mode. (Ref 2) Transmission from Monterey would then be limited to a single computer on each main line receiving data and operating in the full duplex mode. These single line computers would store and forward information for additional stations. This software change would allow the most efficient use of the links, reduce required terminal complexity and allow the adoption of an automatic acknowledgement in response to the stop pattern.

The transmission block size could be increased, this has not been accomplished primarily because of the desire to keep the CDC 160A's as back-up for the main communication function. A larger block size would overload the 160A memory capability.

An error detection system that depends on retransmission for correction is simple and effective. Extensive FNWC in-house analysis has been made of other error correction systems, but, as far as FNWC is concerned,

none have been found to be as efficient relative to through-put rate or as positive as the system in existence. A change to an error correction code would require a major rewrite of the transmission programs. (Ref 5) Retransmission does not overload the system at the present time and other computer networks do use this method for positive transfer of data.

The entire system is clearly line bound, that is, it is limited in total performance by the speed at which the desired information can be transmitted over the leased communications lines. (Ref 32, p. 56) This limitation stems from the requirement to utilize voice-grade, long-lines for data transmission. These lines by their very nature limit the speed of transmission.

3. NEDN/NIDN

Dedicated lines for the NEDN are not necessary. Some form of time sharing of the circuits as an economical solution to the data transfer problem is necessary and the NEDN/NIDN share system does do this. The NIDN takes up unused space on the circuits. Even though the initial NEDN through-put was increased on the east line when the NEDN/NIDN was inaugurated, the Naval Weather Service could use more through-put. The addition of NIDN to any of the circuits cuts the weather data in half. Although the system may not be overloaded at present, more bandwidth or more through-put could allow the Naval Weather Service to provide more analyses and finer resolution of their output. One

concern of the Naval Weather Service is the possibility of the circuit preemption for high priority intelligence when the NEDN/NIDN is fully implemented.

The concept of multiplexing weather and intelligence information together to more properly utilize existing circuits is sound. Dedicated leased long-lines are expensive. The services should be striving to pack all the data possible onto these channels. In the case of the NEDN/NIDN project, there are at least two major problems to consider. The project has been long term, begun in 1969, and is not yet in full operation. One problem of long research and development periods is the inability to take advantage of current technology. An example here is the computer picked for the multiplexing function, the PDP-8/E, which might not be used if the system were being planned today. (Ref 9) Why not use the standardized AN/UYK-20? Another problem is that the system may be unessential even before it is fully implemented and yet the planners go ahead because that is the loyal thing to do. Other circuits are now available for the NIDN information and should be used. It is understood that the DIN/DSSCS could carry the NIDN information. Two sources stated that these circuits are operating at 26-30% utilization. Addition of the NIDN data would only add 2% at most. (Ref 9) The cost of the NEDN/NIDN project to date is a sunk cost and irrelevant concerning any future decision that could be made about the disposition of the networks. More information about the DIN/DSSCS has not been included in this study because of the DIN/DSSCS classification.

Although the NEDN controls its own links, the Weather Service was never included on the distribution list of any planning documents for NEDN/NIDN. NEDN/NIDN planners have gone so far as to call the new network the osis communications network on at least one blueprint. (Ref 14) The implementation plan for NEDN/NIDN netting, calling for action by both NAVWEASER and NAVINTCOM was only distributed to NAVELEX. This is as it should be, perhaps, since NELC is working for NAVELEX on this project. However, there is no evidence that the users ever received the document or responded to the request for decisions or evaluations of impacts called for. If they were asked, this information never filtered down to FNWC Monterey. The NEDN support department at FNWC thought that NEDN/NIDN was a dead issue until the author's trip to San Diego. (Ref 2)

4. AWN

A description of the AWN was included in this study for comparison purposes. The AWN enables the AFGWC to begin receiving raw weather data within ten minutes of the time of observation and the process of refining forecasts begins fifteen minutes later. This service is accomplished by using 2400 BPS lines under the control of the AFCS. At least one of these lines is a private leased line (Carswell-Fuchu). Even though this is a private leased line, the Air Force communicators have routed it to NAVCOMMSTA SFRAN where it is packed into a high density overseas link. This is one example of resourceful communication procedures.

By limiting the speed of transmission to 2400 BPS, the data circuits are compatible with a number of existing military communications systems including AUTODIN which could be used for alternate routing. The single critical link between Carswell and Offutt operates at 4800 BPS. These limitations on the speed of transmission do not appear to effect the timeliness of the data flow.

5. AUTODIN

A long term objective of the Director, Telecommunications and Command and Control Systems in the Office of the Secretary of Defense is to design common terminal hardware and software which would allow the AUTODIN system to be used for data networks on a communications terminal-to-terminal basis as well as for record communications. (Ref 34) AUTODIN was considered by the author as an answer to the cost effective transfer of NEDN data, however, there appears to be a better alternative for the bulk of the data transfer and that AUTODIN should only be used for two of the NEDN links.

6. ARPANET

A description of the ARPANET was originally included as an example of a computer network for comparison purposes. After studying the ARPANET and its advantages, it appears that the NEDN data could be placed on this network and that this shift would be economical and beneficial. A Rand study, published in June 1972, concludes that design goals for the ARPA communication SUBNET have

been exceeded. The undetected transmission error rate is 1 in 10 TERABITS of data. Average response time for an 8000 bit message is 0.3 seconds. Since the SUBNET can use available alternate routes between sites, the average outage between sites has been less than 0.5 percent. (Ref 20, p. 13)

The main advantage of the ARPANET is that it allows a heterogeneous collection of computers to communicate. Other advantages include time sharing of high data rate lines which allows efficient use of communication facilities, low usage charges and geographic sharing of resources. (Ref 20, p. 11-12) The service is so attractive that the University of Illinois has chosen to depend upon ARPANET almost exclusively, obtaining over 90% of their computational requirements through its use. (Ref 21, p. 56)

The main disadvantage of the ARPANET for the potential military user is that the system is not secure. This disadvantage is critical to the purpose of this paper since the decision has been made to cover the weather information on the NEDN. It appears that this problem could be solved but it is not known if the solution would be simple. Since the IMP accepts data from the host in any form, without restriction, including binary text, it would seem that it would accept a random data stream from a TSEC/KG-13 or similar crypto unit. The problem is how to leave the leader in the clear and encrypt the data so that the SUBNET can properly route the message. Mr. B.E. Bradford of the

NEDN support department feels that the best way to solve the security problem is to encrypt the data within the host computer. (Ref 2) Professor Cerf at Stanford stated emphatically that NSA would not accept this approach. He also stated that Bolt, Beranek and Newman, Inc. was working on an acceptable cryptographic device to cover ARPANET. (ref 35) An assumption is made here that this problem will be overcome. Commercial companies might also be interested in the solution of this problem since many of them are concerned with privacy of data.

Would the switch to ARPANET for NEDN be cost effective? The cost of leasing the NEDN circuits is $39,228.62 per month or $470,743.44 per year. Placing the NEDN on the ARPANET and rearranging some hardware locations could eliminate the need for four of these circuits, plus an additional circuit, potentially cutting the lease bill in half. The switch to ARPANET would envolve four nodes, Monterey, Pearl Harbor, Norfolk and London. FNWC Monterey is already part of the ARPANET. There should be no direct cost envolved at that node. Pearl Harbor and Norfolk have sufficient computer power (CDC 8490's and CDC 3100's) to act as TIP's. A computer complex would have to be procured for London. As suggested previously, this hardware could be obtained from FWF Suitland. ARPANET has nodes at Hawaii and London so joining the network at these two locations would only involve local circuit costs. The node at Norfolk would probably be connected to the existing network through

the Mitre Corporation in McLean, Virginia. Cost of this link as well as other local circuit costs should be included in the total cost of the network as the cost to the user of ARPANET does not depend on the distance to be covered. ARPA has procured the 50 KPBS lines for the network through the Washington office of AT&T. (Ref 25) If this change were adopted, funding for the NEDN would be shifted to the DCA budget.

7. Potential Savings

Adopting all the changes proposed by this study would allow the Navy to give up the following circuits:

Commercial Leased Designator	Between	Monthly Lease Rate
GDA 90650-67	Monterey-Pearl	$ 5,950.00
GDA 90660	Monterey-Norfolk	1,820.96
DPE 0324	Norfolk-Rota	11,704.90
GDA 90659	Norfolk-Suitland	659.71
GDA 90665	Monterey-Offutt	1,274.00
TOTAL MONTHLY COST		$21,409.57

The potential saving is $256,914.84 per year. Everything has a cost and this proposal is no exception. The projected ARPANET cost for 1975 is $35,000 per year per node. There would be software modification costs for the NEDN but these are difficult to estimate. Assuming four nodes for NEDN, the annual cost would be $140,000 per year. The net saving would be approximately $116,000 per year or over one million dollars in ten years.

If it is possible to shift the two remaining NEDN links (Pearl Harbor-Guam and London-Rota) to AUTODIN, then the Navy could save an additional $229,116.60 per year.

8. Proposals for Study

a. FWF Suitland

A detailed analysis is needed to determine if it is necessary to maintain FWF Suitland. Eliminating this facility would save the operating cost and the costs of the circuits terminating there as well as free a computer complex which could then be moved to London for EDP transfer of weather information to that location. The reasons given to the author for keeping FWF Suitland in the system include using that location for a back-up for Monterey and providing an interface with the NMC for receipt of satellite information for the rest of the NEDN system. The Air Force could serve both of these functions for the Navy. The GWC and FNWC are linked by ARPANET and could serve as mutual back-ups. The Air Force AWN interfaces with the NWS in two places, the NMC and Kansas City. Information from the NWS could be sent to FNWC via Carswell. Originally, the weather facility at Suitland was a joint venture between the Air Force and the Navy. The Navy moved out first and established its own facility. Later, the AWS moved out of the Washington area completely and established the GWC at Offutt AFB in Nebraska. An interesting fact to consider at this point is that the Pentagon weather support is provided by the GWC

from Offutt via a high speed (50 KBPS) line. (Ref 33) It may be time for Navy weather to move out of the Washington area and establish its headquarters at Monterey. If it is necessary to maintain FWF Suitland, then the multiplexing of the NEDN/NIDN networks should be accomplished there, if done at all, thus saving at the very least one line between Suitland and Norfolk. Why should the NAVWEASER and NAVINTCOM maintain their own separate lines between these two points?

b. Defense Geophysical Service

One might question the existence of three separate but connected weather services with their own communication networks. The future may well see the establishment of a Defense Geophysical Service (DGS) which would combine with the Defense Intelligence Agency (DIA) for data transfer and provide full support to the World Wide Military Command and Control System (WWMCCS) using a single network. "Most of our major military missions today require the participation of more than one of the military services. Therefore, our principle concern now must be centered on what is required by the defense establishment as a whole to perform a particular military mission - not what is required of a particular service to perform its part of that mission." (Ref 36, p. 65) This statement could be applied to a military support function such as the weather. The Defense Department can no longer afford wasteful duplication. It is interesting to note that the

United States is one of a few nations that has two meteorological organizations which are independent of the state meteorological service. (Ref 37) In our case, NOAA, under the Department of Commerce, is the recognized service. Included under NOAA, among other agencies, are the National Weather and Environmental Data Services. Within the Defense Department, the AWS and the Naval Weather Service Command, both independent of the state service, appear to be competitive and overlapping services. While these separate services do cooperate in some cases and exchange information, they are still in a sense competing. The most efficient use of personnel and resources would avoid all duplication of effort. A single military geophysical service might solve these problems. We should analyze our total military needs for weather capability across service lines. This should foster a better balanced military weather program and weed out unnecessary duplication. Then and only then can we properly design the communication networks and procure the circuits to collect and distribute weather information in the most cost effective manner.

A conservative estimate of the magnitude of the study proposed would be ten man years of effort. That is, a ten man investigative team composed of experts in the fields of weather, computers and communications with service representation working together for an entire year to study the total military weather system. (Ref 33) It is recognized that the individual services have unique needs and might still require semi-separate systems. The comprehensive

study and analysis should provide solutions to this problem as well as ways to combine the best features of the Navy and Air Force systems. The Army currently receives weather support from the Air Force system.

III. CONCLUSIONS/RECOMMENDATIONS

A. CONCLUSIONS

Action can be taken to reduce the cost of transmitting Naval Environmental Data. Two reasonable alternatives are available to accomplish this reduction in cost. Shift the NEDN information to AUTODIN or ARPANET. The developer of ARPANET forsees the gradual transfer of traffic from other data communications networks to ARPANET to take advantage of its economy and reliability. (Ref 24, p. 8) The author concludes that the bulk of the NEDN information could and should be switched to the ARPANET and that this change would be cost effective. The potential savings would amount to approximately $116,000 per year. The potential benefits are better service, finer resolution of output and more detailed analyses. The two remaining NEDN links that would not readily fit on the ARPANET might be switched to AUTODIN.

The author concludes that the Navy should give up the 4800 BPS line between FNWC Monterey and GWC Offutt. These places are already nodes in the ARPANET. The potential savings here is $15,288 per year. The potential benefit is faster and better service between these two weather centers.

The author concludes that the Navy should stop the NEDN/NIDN project. The NEDN is an expensive network relying entirely on private leased lines. Multiplexing intelligence

data on top of weather data will only harden the argument to hold on to these circuits. The concept of properly utilizing existing circuits is sound, but not if you consider there are already existing circuits which could carry the intelligence information. The NIDN data should be put on the existing DIN/DSSCS.

It appears to be desirable to the author from the standpoint of minimizing communication costs to revert to a single military interface with the National Weather Service. It is suggested that the Air Force provide this interface and relay the data to Monterey via Carswell. One of the reasons for this conclusion is that the Air Force already interfaces with the NWS through Kansas City as well as Suitland. An agreement between the Air Force and the Navy could put this plan into operation. The Navy could close FWF Suitland and move the computer complex to London. Back-up for FNWC Monterey computers could be provided by GWC Offutt computers. Satellite photographs could be provided by the NMC through Carswell and from the GWC Offutt by way of ARPANET.

There is some competition and duplication of effort present in the Defense Department between the Air Weather Service and the Naval Weather Service Command. The author feels that major cost savings could be realized by a consolidation program. Cooperation between the Air Force and the Navy would allow the Navy to eliminate FWF Suitland from its system as the need would no longer exist to main-

tain it. Cooperation between these two services would eliminate duplication of effort in such areas as environmental satellite data and the interface with the National Weather Service. Although not discussed in this paper, another area of duplication of effort that could be studied is computer flight plans. Only a long term study, such as that suggested in the analysis would allow the necessary consolidation of effort. This is particularly applicable to the reduction of redundant weather communication links.

The research for this thesis has further blurred the distinction between computer technology and the communications industry. Commercial companies are finding it cost effective to combine the functions of data processing and telecommunications. (Ref 38, p. 6-19) The Navy should study this approach to management.

This thesis clearly demonstrates the need for communication system specialists. The problem is at what level should they function. They should be at a high enough level to exert national influence. Perhaps the best place for these experts would be in the Cabinet level Department of Communications suggested by Mr. Orndorff in a letter to the Chairman, House Subcommittee on Communications and Power. (Ref 39,p. 56)

The Navy can and should take specific steps to improve the overall system. Specific and general recommendations are submitted, which the author feels would improve the Navy position.

The alternative is always to do nothing and wait until an outside agency points out the existing waste and duplication of effort, which may happen sooner than expected in the area this paper studies. During the experience tour for telecommunications systems students, it was learned that the Government Accounting Office was making preliminary inquiries concerning weather circuits at NAVCOMMSTA SFRAN. The GAO may not be in a position to complain yet, but they are definitely interested in what appears to be a fruitful area to save money.

B. RECOMMENDATIONS

The following recommendations would not be accomplished in the order given since some are interdependent. The recommendations are listed by the relative importance the author places on the value of the suggestion.

1. Place the NEDN data on ARPANET from Pearl Harbor to London and stop leasing the circuits listed in the analysis.
2. Investigate the feasibility of placing the Pearl Harbor to Guam and London to Rota NEDN links on AUTODIN.
3. Stop leasing the circuit between FNWC Monterey and GWC Offutt and utilize ARPANET for the exchange of data between these two centers.
4. Stop the NEDN/NIDN project and place the NIDN data on the DIN/DSSCS.
5. Investigate the feasibility of closing FWF Suitland.
6. Move the computer complex from Suitland to London for EDP transfer of weather using the Atlantic ARPA link.
7. Defense Department establish a single military interface with the National Weather Service.

8. Navy and Air Force investigate use of the AFGWC and FNWC weather computers as mutual back-ups.

9. Navy and Air Force investigate use of one computer flight plan program available to all services.

10. Naval Weather Service expidite the NEDN software change which would convert from broadcast to point-to-point mode of operation.

11. Conduct a Defense Department study and establish the feasibility/desirability of a Defense Geophysical Service.

12. Study the combining of data processing and communications functions.

13. Train and use communication system specialists.

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